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Evaluation of rotary dehumidifier performance with and without heated purge☆

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Abstract

In this paper we evaluate the potential benefits from separating process air stream at the exit of rotary dehumidifier into two streams. One air stream, hot and humid, is called purge air stream and other is remaining process air stream. The remaining process air stream has a lower temperature and humidity ratio as result of separation of initial hot process air stream. It is found that as the purge angle increases the exit humidity ratio of remaining process air stream decreases up to a point where it reaches a minimum. The purge angle for which this occurs is named "effective purge angle". The effective purge angles for different splits between adsorption and desorption side of the rotary dehumidifier, various regeneration temperatures, non-dimensional lengths and their corresponding optimum non-dimensional times are determined. An existing finite-difference model, developed by the authors of this paper, for simulation of desiccant wheel performance is extended to account for the separation of the process air stream at the exit of rotary dehumidifier and later mixing of purge air stream and outside air to form the regeneration air stream. The performance of desiccant wheel with heated "effective purge angle" is evaluated and compared with performance of the same wheel without purge angle at all. It is found, for all cases considered in this study, that having heated "effective purge angle" has overall positive effect on the performance of the rotary dehumidifier.

Keywords: Desiccant wheel; Dehumidification; Heated purge angle

1. Introduction

Rotary dehumidifiers are used to dry moist ventilation ambient air in many air conditioning systems. In numerous applications, rotary dehumidifiers are used when the latent load is large in comparison with the sensible load and when cost of energy to regenerate desiccant wheel is low as compared to the cost of energy to dehumidify the air by chilling it below its dew point in a vapor compression air conditioning system. The dehumidification of outside air within rotary dehumidifier takes place as result of a difference between the water vapor pressure at the desiccant surface and surrounding air. When the water vapor pressure at the desiccant surface is lower than that of the air, the desiccant adsorbs moisture. When the surface water vapor pressure is higher than that of the surrounding air, the desiccant releases the moisture, which is termed desorption.

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Nomenclature

c_s, c_d, c_{Pda}, c_{wv}, c_{lw}, c_{wr}	Specific heat of support material, desiccant, dry air, water vapor, liquid water, reference specific heat
L	Channel length
Le	Lewis number
$\dot{m}_{da}$	Mass flow rate of dry air
NTU	Number of thermal transfer units
P_{atm}, P_{ws}	Absolute pressure of air streams, saturation pressure
T_a, T_w	Temperature of air stream, channel wall
W_b	Moisture content of the desiccant
Y_a	Humidity ratio of air stream
ads	Adsorption
des	Desorption

Greek symbols

δ	Half of the height of channel
λ	Wall thickness
ρ_{da}, ρ_w	Density of dry air, density of the wheel
$\theta_{ads.}$, θ_{purge}	Adsorption angle, purge angle

In recent years, there have been number of studies dealing with optimum performance of desiccant wheels. The influence of process and regeneration air streams conditions on the optimum performance of rotary dehumidifiers were analyzed by Zheng et al. [1]. An in depth study of the effect of desiccant matrix properties on the performance of rotary dehumidifiers was presented by Jurinak and Mitchell [2]. The matrix properties considered were the sorption isotherm shape, the heat of sorption, the matrix thermal capacity, the matrix moisture diffusivity and the sorption isotherm hysteresis. It was shown that sorption properties have a significant affect on the desiccant wheel performance. The influence of sorption properties on optimum dehumidification performance of regenerative dehumidifiers was also studied by Golubovic et al. [3] and Dini and Worek [4]. Zhang and Niu [5] studied effects of rotational speed, the number of transfer units and the specific surface area on desiccant wheel performance. The impact of wall thickness on the heat and moisture transfers in rotary dehumidifiers for air dehumidification was considered by Niu and Zhang [6].

In this paper, the enhancement of the rotary dehumidifier performance by separating process air stream into two streams at the exit of desiccant wheel is analyzed. A finite difference scheme, developed by the authors for simulation of rotary dehumidifier performance, is extended to take into account separation of the process air stream at the exit of the wheel and later mixing of purge air stream with outside air to form regeneration air stream. Numerical simulations of desiccant wheel with heated “effective purge angle” are performed and compared to the performances of the desiccant wheel without heated purge.

2. Modeling of a rotary adiabatic dehumidifier

A schematic of a rotary adiabatic dehumidifier is shown in Fig. 1. The desiccant wheel is a rotary cylindrical wheel that consists of a large number of parallel channels. The channel walls can be coated or impregnated with a desiccant material. The process air stream, which is supplied to a conditioned space after being dehumidified and cooled, passes through adsorption side of the desiccant wheel. The regeneration air, heated by an external heat source, passes through the desorption side of desiccant wheel and regenerates the desiccant. Within the desiccant wheel, heat and mass transfer processes take place between the air streams and the desiccant wheel.

In order to simplify the analysis, the following assumptions are typically made (Zheng and Worek [7]). These are:

1. The accumulation of moisture and energy within the infinitesimal control volume can be neglected.